APPENDIX B

FUEL PROPERTIES AND CHARACTERISTICS

(from CPIA Publication 394, "Hazards of Chemical Rockets and Propellants", by John Hopkins University, Applied Physics Laboratory, Laurel, MD, Sept. 1984)

NAME:	LH_2 — Liquid Hydrogen
MILITARY HAZARD CLASSIFICATION:	Group III
DOT CLASSIFICATION:	Flammable Liquified gas
QUANTITY PER VEHICLE:	3,400 lb (Centaur)
APPLICATION:	Centaur

PROPERTIES AND CHARACTERISTICS

COMPOSITION:	99.79% para-hydrogen and 0.21% ortho-hydrogen.
APPEARANCE:	High purity Liquid Hydrogen is transparent and colorless.
STABILITY:	Liquid Hydrogen is chemically stable. Physically stable only when stored under suitable conditions.
FREEZING POINT:	-435°F
BOILING POINT:	-423°F
DENSITY:	0.59 lb/gal. at -423°F
CRITICAL PRESSURE:	188 PSIA
CRITICAL TEMPERATURE:	-400°F
ODOR:	None

HAZARDS

PHYSIOLOGICAL:	Human contact with liquid hydrogen or uninsulated lines can result in severe frost bite. Hydrogen gas acts as a simple asphyxiant that can be breathed in high concentrations without producing systematic effects. However, if the concentration is high enough to significantly reduce the

	amount of oxygen in the air, the effects of oxygen deprivation will be produced.
EXPLOSION:	Unconfined hydrogen-air mixtures generally burn rapidly without detonation. However, in confined areas or when ignition is caused by a shock source or small explosive charge, the mixture can detonate. An explosion hazard can exist if liquid hydrogen is contaminated with solid oxygen or solidified oxygen enriched air.
THRESHOLD LIMIT VALUE:	None

NAME:	LOX-Liquid Oxygen
MILITARY HAZARD CLASSIFICATION:	II
MILITARY STORAGE COMPATIBILITY:	LIQ-A
DOT CLASSIFICATION:	Non-Flammable Liquid
QUANTITY PER VEHICLE:	146,300 lb (an additional 15,300 lb)
APPLICATION:	First Stage Oxidizer

PROPERTIES AND CHARACTERISTICS

COMPOSITION:	99.5% oxygen
APPEARANCE:	Light blue transparent liquid. Boils vigorously at ambient conditions.
STABILITY:	Liquid oxygen is chemically stable, is not shock sensitive and will not decompose.
FREEZING POINT:	-361°F
BOILING POINT:	297°F
DENSITY:	9.53 lb/gal. at -297.4°F
CRITICAL PRESSURE:	737 PSIA
CRITICAL TEMPERATURE:	-181°F
ODOR:	None

HAZARDS

PHYSIOLOGICAL:	Human contact with liquid oxygen or uninsulated lines can result in severe frost bite. Oxygen gas will not cause toxic effects. Gaseous oxygen from the liquid is absorbed by clothing and any ignition source may cause flare burning.

EXPLOSION:	When mixed with liquid oxygen, all materials that burn represent explosive hazards.
THRESHOLD LIMIT VALUE:	None

NAME:	TEA (Triethyl aluminum) TEB (Triethyl boron)
MILITARY HAZARD CLASSIFICATION:	III
MILITARY STORAGE COMPATIBILITY:	LIQ-C
DOT CLASSIFICATION:	Flammable Liquid
QUANTITY PER VEHICLE:	0.17 lb
APPLICATION:	TEA in first stage main engine
	TEA/TEB in vernier engines

PROPERTIES AND CHARACTERISTICS

COMPOSITION:	100% TEA in main engine	
	15% TEA, 85% TEB in vernier engines	
APPEARANCE:	Colorless liquid	
STABILITY:	TEA reacts violently with water and organic and inorganic acids. TEB reacts violently with oxygen.	
	TEA	TEB
FREEZING POINT:	-52°F	-134°F
BOILING POINT:	+381°F	+203°F
DENSITY:	52 lb/cu. ft at 70°F	43 lb/cu. ft
FLASH POINT:	Ignites spontaneously in air at room temperature.	
ODOR:	Combustion products have pungent ammonia-like odor.	

HAZARDS

PHYSIOLOGICAL:	TEA and TEB will destroy living tissue on contact.
	Combustion products are highly toxic.

FLAMMABILITY:	TEA and TEB ignites spontaneously in air at room temperature.
THRESHOLD LIMIT VALUE:	Zero

NAME:	Nitrogen Tetroxide
MILITARY HAZARD CLASSIFICATION:	I
MILITARY STORAGE COMPATIBILITY:	LIQ-A
DOT CLASSIFICATION:	Poison Liquid A
QUANTITY PER VEHICLE:	6,228 lb
APPLICATION:	Second stage oxidizer

PROPERTIES AND CHARACTERISTICS

COMPOSITION:	99.5% N_2O_4
APPEARANCE:	Reddish-brown liquid with yellowish to reddish-brown fumes.
STABILITY:	N_2O_4 is very stable at room temperature. At +302°F it begins to dissociate into nitric oxide and oxygen, but upon cooling it reforms into N_2O_4.
FREEZING POINT:	+11.8°F
BOILING POINT:	+70.1°F
DENSITY:	12.1 lb/cu. gal. at 68°F
CRITICAL TEMPERATURE:	1,469 psia
CRITICAL PRESSURE:	+316.8°F
FLASH POINT:	None
ODOR:	Characteristic irritating, pungent and acid-like odor.

HAZARDS

PHYSIOLOGICAL:	N_2O_4 liquid is corrosive and can cause severe burns of the skin and eyes unless it is immediately removed. Inhalation of N_2O_4 vapors is

	normally the most serious hazard.
SYMPTOMS OF POISONING:	Irritation of the eyes and throat, cough, tightness of the chest, and nausea - are slight and may not be noticed. Then hours afterward, severe symptoms begin; their onset may be sudden and precipitated by exertion. Coughing, a feeling of constriction in the chest, and difficult breathing are typical.
FLAMMABILITY:	N_2O_4 is a corrosive agent whose corrosiveness is enhanced in the presence of water. It is not sensitive to shock, heat, or detonation. It is not flammable in air but will support combustion.
THRESHOLD LIMIT VALUE:	3 ppm for NO_2 2.5 ppm for N_2O_4 At no time will personnel be subjected to any concentration greater than TLV.

NAME:	RP-1
MILITARY HAZARD CLASSIFICATION:	I
MILITARY STORAGE COMPATIBILITY:	LIQ-C
DOT CLASSIFICATION:	Flammable Liquid
QUANTITY PER VEHICLE:	67,000 lb (an additional 11,000 lb.)
APPLICATION:	RP-1 is a thermally stable kerosene having a very high energy content. It is used for first stage fuel.

PROPERTIES AND CHARACTERISTICS

COMPOSITION:	Hydrocarbon
APPEARANCE:	Clear liquid ranging in color from water-white to a pale yellow.
STABILITY:	A mixture of RP-1 and liquid oxygen forms a gel which may explode upon being subjected to impact or shock.
FREEZING POINT:	-40°F Max.
BOILING POINT:	350° to 525°F
DENSITY:	49.95 to 50.82 lb/ft^3 at 60°F
FLASH POINT:	110°F
ODOR:	Strong, kerosene-like

HAZARDS

PHYSIOLOGICAL:	Inhaling vapors may cause headache, dizziness or nausea. Continuous contact with the skin can cause irritation.
EXPLOSION:	A mixture of vapor and air is dangerous and should be considered as an explosive

	mixture.
THRESHOLD LIMIT VALUE:	500 PPM in air. At no time will personnel be subjected to any concentration greater than the threshold limit value (TLV).

NAME:	Aerozine 50
MILITARY HAZARD CLASSIFICATION:	III
MILITARY STORAGE COMPATIBILITY:	LIQ-C
DOT CLASSIFICATION:	Flammable Liquid
QUANTITY PER VEHICLE:	3,892 lb
APPLICATION:	Second-stage fuel

PROPERTIES AND CHARACTERISTICS

COMPOSITION:	Mixture of 50% UDMH and 50% hydrazine
APPEARANCE:	Clear, colorless liquid
STABILITY:	A-50 is thermally stable and is not shock or friction sensitive.
FREEZING POINT:	+18.8°F
BOILING POINT:	+158.2°F
DENSITY:	56.1 lb/cu. ft at 77°F
FLASH POINT:	+104°F
CRITICAL TEMPERATURE:	+634°F
CRITICAL PRESSURE:	1,696 psia
ODOR:	Ammonia gas

HAZARDS

PHYSIOLOGICAL:	The liquid can be absorbed through the skin; the vapors can be inhaled. Exposure may cause irritation of the mucous membranes of the eyes, respiratory passages, lungs,and gastro-intestinal tract. Direct skin contact can cause severe burns.

	MMH and UDMH are convulsant agents, irritants to the respiratory tract and eyes and may irritate the skin. They are absorbed by the skin, oral and inhalation routes. Hydrazine fuels form carcinogenic nitrosamine compounds. Also, ACGIH has listed the hydrazines as "Suspected Human Carcinogens."
EXPLOSIVE:	Liquid is flammable and reacts violently with acids and oxidizing agents.
THRESHOLD LIMIT VALUE:	0.5 ppm in air.
	At no time will personnel be subjected to any concentration greater than the TLV.

NAME:	Oronite Extreme Pressure Additive
MILITARY HAZARD CLASSIFICATION:	None
MILITARY STORAGE COMPATIBILITY:	None
DOT CLASSIFICATION:	Flammable Liquid
QUANTITY PER VEHICLE:	5.96 lb
APPLICATION:	First-stage booster engine lubricant.

PROPERTIES AND CHARACTERISTICS

COMPOSITION:	Phosphorus, zinc, sulphur, calcium
APPEARANCE:	Transparent, light orange oil
STABILITY:	Stable at controlled storage temperature below +100°F
FREEZING POINT:	+17°F
BOILING POINT:	Not Available
DENSITY:	67.8 lb/cu. ft at 60°F
FLASH POINT:	+340°F
ODOR:	Foul, sulphur-like smell

HAZARDS

PHYSIOLOGICAL:	None. Inhaling vapors is unpleasant.
EXPLOSION:	A mixture of additive and liquid oxygen forms a gel which may explode upon being subjected to impact or shock; however, such contact does not normally occur. A mixture of additive and fuel is normal in the lubrication system and is not hazardous.
THRESHOLD LIMIT VALUE:	None